Defense Technical Information Center Compilation Part Notice

ADP013070

TITLE: Regular Trends in Fine Structure and Localization of Excitons in Type II GaAs/AlAs Superlattices With a Gradient of Composition

DISTRIBUTION: Approved for public release, distribution unlimited
Availability: Hard copy only.

This paper is part of the following report:

TITLE: Nanostructures: Physics and Technology International Symposium [8th] Held in St. Petersburg, Russia on June 19-23, 2000 Proceedings

To order the complete compilation report, use: ADA407315

The component part is provided here to allow users access to individually authored sections of proceedings, annals, symposia, etc. However, the component should be considered within the context of the overall compilation report and not as a stand-alone technical report.

The following component part numbers comprise the compilation report:
ADP013002 thru ADP013146

8th Int. Symp. "Nanostructures: Physics and Technology"
St Petersburg, Russia, June 19–23, 2000

Regular trends in fine structure and localization of excitons in type II GaAs/AlAs superlattices with a gradient of composition.

P. G. Baranov†, *N. G. Romanov*†, A. Hofstaetter‡, B. K. Meyer‡, A. Scharmann‡, W. von Foerster‡, F. J. Ahlers# and K. Pierz#
†Ioffe Physico-Technical Institute, St Petersburg, Russia
‡ 1. Physics Institute, University of Giessen, Heinrich-Buff-Ring 16, D-35392 Giessen, Germany
# Physikalische-Technische Bundesanstalt, Braunschweig, Germany

Abstract. Optically detected magnetic resonance and level anticrossing spectroscopy were used to reveal regular trends in the behavior of the fine structure of excitons, their dynamic properties and localization at the opposite interfaces in type II GaAs/AlAs superlattices grown by MBE with a gradient of layer thicknesses in the SL plane.

Introduction

Optical and electronic properties of quantum well heterostructures are particularly sensitive to disorder at the interface between the different compounds forming the well and the barrier. In type II structures electrons and holes are confined in the adjacent layers and the spatially indirect interband optical transitions arise due to the electron-hole overlap within a very narrow region containing the interface. Excitons in such structures are localized at the interfaces and can be used as probes sensitive to the interface microstructure. In type II GaAs/AlAs SL's radiative lifetimes lie in the μs range which makes possible to use optically detected magnetic resonance (ODMR) for direct measurements of electron and hole g-factors and the exciton exchange (fine structure) splittings with a radiospectroscopy precision [1, 2]. Level anticrossing (LAC) spectroscopy of SL's was developed on the basis of ODMR and provided important complementary information [3, 4]. Due to the lowered point symmetry C_{2v} of the interface all four levels of heavy-hole excitons are split. One to one correspondence was established between the order of the exciton radiative levels and the type of interface at which exciton is localized: the lowest radiative levels are [110] polarized for excitons at the normal (AlAs on GaAs) interface and [$1\bar{1}0$] polarized for the inverted (GaAs on AlAs) interface [5, 6]. In addition, a difference in the fine structure splittings caused by the asymmetry in the interface composition profiles was found for excitons localized at the opposite interfaces [7]. Application of ODMR for a study of exciton dynamic properties was reported in [8]. In all GaAs/AlAs superlattices in-plane linear polarization of luminescence of some per cent was found which correlated with the exciton preferential localization [9].

In the present work we study regular trends and variations of the exciton localization and fine structure splitting in type II GaAs/AlAs SL grown with a gradient of GaAs/AlAs composition.

1. Results and discussion

GaAs SL were grown by MBE with 30 s. interruptions after GaAs layers on the 2 inch (001) GaAs substrate kept at 620°C. A smooth variation of GaAs/AlAs composition in the

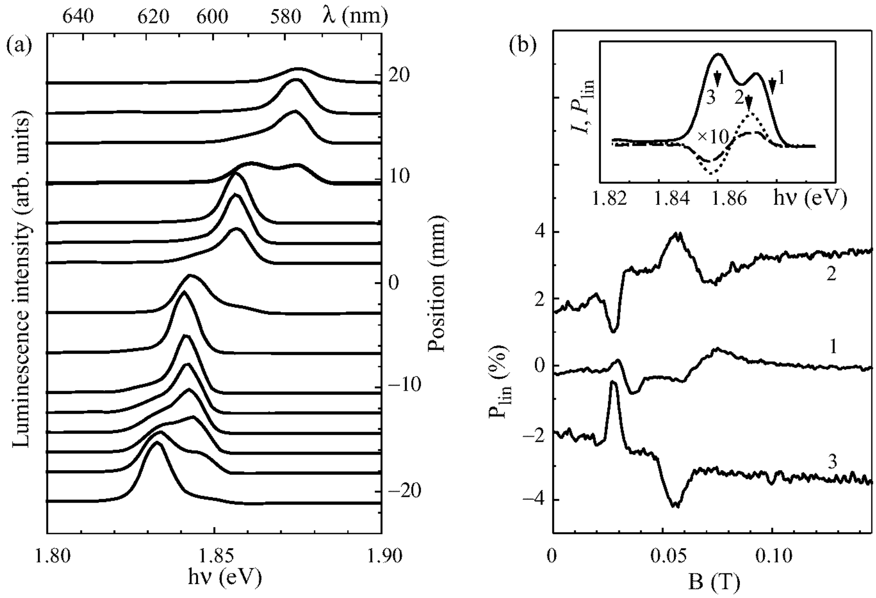

Fig. 1. (a) Luminescence spectra as a function of position x relative to the centre of the wafer. (b) Level anticrossing signals for a point $x = 10$ mm measured at different energies marked in the insert. Dashed and dotted lines in the insert show linear polarization at $B = 0$ and $B = 0.1$ T. $B \parallel [001]$. $T = 1.6$ K.

SL plane from 18 Å/18 Å to 23 Å/23 Å was obtained. It was controlled by X-ray diagnostics (XRD). Luminescence was excited far above the band gap with an Ar^+ laser. ODMR at 24 and 35 GHz and LAC was measured by monitoring circular and linear polarization of luminescence, respectively. 2 mm wide samples were cut along the substrate diameters parallel to [110] and [$1\bar{1}0$] and could be shifted along the axis of the microwave cavity allowing spatially selective measurements.

Figure 1(a) shows variations of luminescence spectra as a function of a position of the excitation spot ($x = 0$ corresponds to the centre of the wafer). According to XRD data GaAs/AlAs composition changed from 18.6 Å/17.8 Å ($x = -22$ mm) to 21.8 Å/23.5 Å ($x = 22$ mm).

LAC signals measured for at $x = 10$ mm where a doublet luminescence is observed, are shown in Fig. 1(b). Insert shows the luminescence spectrum and the linear polarization signals at $B = 0$ (dashed line) and $B = 0.1$ T (dotted line). Analysis of LAC allows to follow variations of the exciton localization at the opposite interfaces. This is illustrated in Fig. 2(a) which shows a decomposition of the observed LAC signals. Excitons at the opposite interfaces have inverted order of the radiative levels (different signs of LAC) and different exchange splittings (different resonance fields). Figure 2(b) shows ODMR measured as variations of σ^+ and σ^- light caused by resonant microwaves chopped at 1 and 100 kHz. Such measurements allow to reveal different exciton dynamic properties similar to [8].

In the ODMR spectra shown in Fig. 3 resonance signals corresponding to spin-flips of exciton holes and exciton electrons are observed. Their positions and splittings are different for the two emission lines. This is connected with the exciton localization in the regions

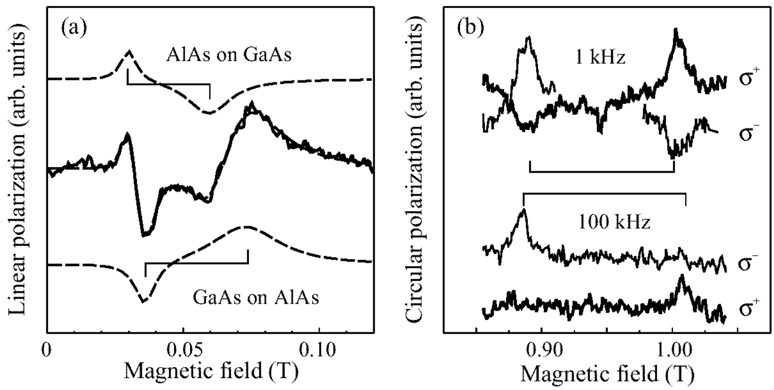

Fig. 2. (a) Decomposition of level anticrossing signals (for $x = 10$ mm, $h\nu = 1.85$ eV) into LAC of excitons localized at the normal (AlAs on GaAs) and inverted (GaAs on AlAs) interface. (b) 24 GHz ODMR measured on the two circularly polarized components of emission with 1 kHz and 100 kHz choping of microwaves.

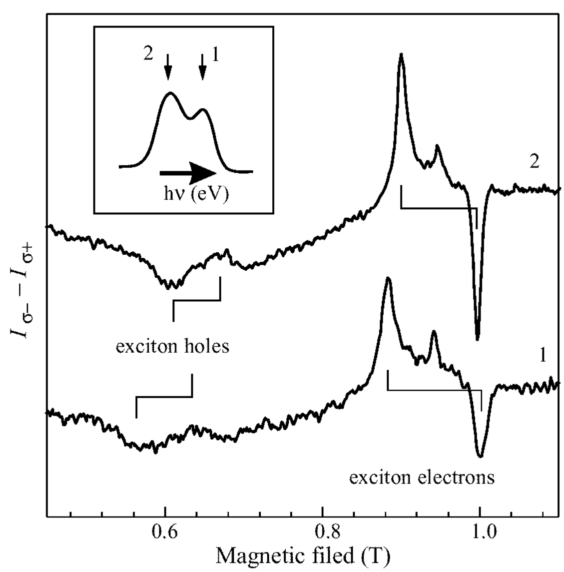

Fig. 3. 24 GHz ODMR spectra taken at the two extrema of emission (for the point $x = 10$ mm). $T = 1.6$ K. $B \parallel [001]$.

with different local periods and GaAs layer widths. On the basis of the dependencies of the isotropic exchange splitting on the SL period and the hole g-factor on the GaAs thickness [2, 4] we can tell that the high energy emission line is due to the excitons localized in the regions 17.5 Å/20.4 Å and the low energy line originates from excitons in the region 19.5 Å/20.7 Å, i.e. low-energy emission comes from c.a. monolayer-high GaAs islands. From LAC (Fig. 2(b)) we can conclude that emission in high-energy line is produced by excitons localized at both normal and inverted interface whereas emission in low-energy line is due to excitons localized at the inverted interface. Excitons localized at the normal and inverted interfaces in the regions with the same local period show different response

time to the applied resonant microwaves (Fig. 2(b)). In addition, effective lifetime of excitons in the high-energy line is shorter as compared to that in the low-energy line.

Similar measurements carried out at different positions on the sample where the layer thicknesses change by more than a monolayer, allowed to reveal regular trends in the exciton fine structure, dynamic behavior and localization at the opposite interfaces. For example, in the regions with close GaAs layer thickness excitons at the inverted interface have larger exchange splitting and shorter effective lifetime, the appearance of low energy line in doublet emission spectra is due to the excitons localized mainly at the inverted interface in the regions of monolayer high GaAs islands, and so on. These regular trends will be discussed in detail.

Acknowledgement

This work was partly supported by the Russian program PhSSN (grant 99-3012).

References

[1] H. W. van Kesteren, E. C. Cosman, W. A. J. A. van der Pool and C. T. Foxon, *Phys. Rev.* **B41**, 5283 (1990).

[2] P. G. Baranov, I. V. Mashkov, N. G. Romanov, P. Lavallard and R. Planel, *Solid State Commun.* **87**, 649 (1993).

[3] P. G. Baranov and N. G. Romanov, in: *The Physics of Semiconductors* ed J. Lockwood (World Scientific), vol 2, p 1400, 1994.

[4] P. G. Baranov and N. G. Romanov, *Phys. Solid State* **41,** 805 (1999).

[5] P. G.Baranov, I. V. Mashkov, N. G. Romanov, C. Gourdon, P. Lavallard and R. Planel *JETP Lett.* **60**, 445 (1994).

[6] C. Gourdon, I. V. Mashkov, P. Lavallard and R. Planel, *Phys. Rev.* **B57**, 3955 (1998).

[7] P. G. Baranov, N. G. Romanov, A. Hofstaetter, A. Scharmann, C. Schnorr, F. J. Ahlers and K. Pierz, *JETP Lett.* **64**, 754 (1996).

[8] P. G. Baranov, N. G. Romanov, A. Hofstaetter *et al.*, *Proc. 6th Int. Symp. Nanostructures: Physics and Technology*, St Petersburg, p 366, 1998.

[9] P. G. Baranov, N. G. Romanov, A. Hofstaetter *et al.*, *Proc. 7th Int. Symp. Nanostructures: Physics and Technology*, St Petersburg, p 360, 1999.